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Input For Bob Alverez Briefing On Project Indalo

The Hall-Otero Agreement was implemented to provide financial and technical support to the Spanish Government to accommodate recovery from a nuclear weapons accident on Spanish soil in January of 1966.

On January 17, 1966, a U.S. Air Force KC-135 tanker and a B-52 bomber collided during an aerial refueling operation. The bomber, carrying four nuclear weapons, disintegrated over Palomares, Spain, a village of about 1500 people. Two nuclear weapons were recovered intact. The other two weapons experienced non-nuclear detonation of the high explosives, with subsequent burning of fissile material, on impact. This resulted in a fissile material aerosol cloud that contaminated approximately 558 acres of uncultivated land, farmed land and urban-developed land. No one on the ground was injured by the incident in Palomares. After decontamination operations, about 10 grams of finely dispersed plutonium-239 (Pu^{239}) remained on the soil.

The U.S., in cooperation with the Spanish Government, initiated Project Indalo, a cleanup operation of the radioactively contaminated area. On February 25, 1966, Dr. John A. Hall, Assistant General Manager for International Activities, Atomic Energy Commission, sent a proposal to Professor Jose Otero, Presidente de la Junta de Energia Nuclear, expanding our collaboration in the fields of health and safety pursuant to the August 16, 1957, U.S.-Spanish Agreement for Cooperation for Civil Uses of Atomic Energy. Dr. Hall proposed investigating various health and safety aspects of fissionable materials when released into a rural agricultural environment. The agreement was accepted by Professor Otero and resulted in establishing a program of technical and financial assistance to Spain for the radiological followup of Palomares residents and their environment. The project has continued since the Hall-Otero Agreement Letter was signed on February 25, 1966. Cooperation continues under the U.S.-Spanish Agreement for Cooperation dated June 28, 1974 which superseded the 1957 agreement and is currently in effect.

Direct funding from the U.S. Department of Energy (DOE) to the Spanish Government provides supplemental assistance to their environmental surveillance program for Palomares and medical follow-up of area residents. The U.S. DOE also funds Oak Ridge National Laboratory (ORNL) to provide project coordination, technical support, training for Spanish scientists, and scientific equipment.

The following is a summary of the project support activities provided over the years since the accident by U.S. funding. Continued funding for these activities was provided as requested by the Spanish Government.

1. In Palomares, Spain:
    a. Transportation of Palomares residents to the Center for Energy, Environment and Technology Research (CIEMAT) in Madrid, Spain for periodic medical evaluations.

b. Measurement of soil, air and vegetation samples for plutonium and americium. Also, a limited number of water and animal tissue samples. Many of the archived samples are being measured for Americium-241 (Am^{241}).
c. One staff person is assigned to man the meteorological station and function on site in Palomares.
d. Costs for collecting and processing samples (mainly air, soil and vegetation).

2. In Madrid, Spain:
   a. Costs for support of Palomares residents in Madrid.
   b. Costs for personnel bioassay measurements for Pu^{239} and Am^{241}.
   c. Scientific and support staff to work on project.
   d. Management and administrative costs.
   e. Costs for the assay of environmental vegetation, soil and air.
   f. Assist with the installation and maintenance of equipment.
   g. Obtain and help install equipment at palomares.

3. In the U.S.:
   a. Provide technical assistance.
   b. Provided training with internal dosimetry and dose calculations.
   c. Obtain equipment needed for bioassay labs at CIEMAT.
   d. Provide internal standards for bioassay quality control.
   e. Assist with data interpretation, especially for in vitro counting bioassay.

Responsibility for the project at U.S. Department of Energy (DOE) was transferred to the Office of Health in August 1990. In the past the U.S. has funded approximately 20% of the costs of conducting the sampling and bioassay program conducted by the Spanish Government.

Initial studies carried out during the first several years following the accident have not produced evidence that the distribution of residual plutonium following the clean-up tended to accumulate in specific environmental systems nor that the health of the Spaniards in the area of the impact was either altered or endangered.

The following tables are provided for your information concerning the observed mortatility in the Palomares population, the causes of death, and the distribution of cancer other than leukemia in the population.

TABLE 1. DISTRIBUTION OF PERCENTAGE OF DEATHS BY AGE OF THE RESIDENTS OF PALOMARES BETWEEN 1966-1984

Age Years	Deaths Number	Simple Percentage	Total Percentage
Less than 1	3	1.92	1.92
1-10	5	3.20	5.12
11-20	0	0	5.12
21-30	6	3.85	8.97
31-40	0	0	8.97
41-50	6	3.85	12.82
51-60	7	4.49	17.31
61-70	26	16.66	33.97
71-80	51	32.70	66.67
81-90	43	27.56	94.23
More than 90	9	5.77	100.00
	156	100%	

Table 2. CAUSES OF DEATH

Causes of Death	Deaths Number	Simple Percentage
Cancers other than leukemia	18	11.53
Leukemia (*)	3	1.92
Others	135	86.53

(*) Of the deaths from leukemia, one male aged 22, died in Barcelona in 1972, one woman in Palomares died in 1975 at age 21 and another male, also in Palomares died in 1980, at age 9. This later individual was born in France where he lived with his parents until he moved to Palomares, already sick, one year before his death. There is no evidence that their deaths resulted from exposure to plutonium from the Palamores accident.

Table 3. DISTRIBUTION BY TYPES OF CANCER OTHER THAN LEUKEMIA WHICH CAUSED DEATH

Type	Deaths Number	Percentage
Digestive system	9	50.0
Respiratory system	2	11.11
Prostate	2	11.11
Bladder	1	5.55
Uterus	1	5.55
Adenoids	1	5.55
Unspecified	2	11.11

The highest external contamination level measured on the ground was about 81 nanocuries/square meter (nCi/m^2). Some residents of Palomares were measured for internal contamination just after the accident. Measurements of Pu in urine and the body of Palomares residents were started in 1967 at CIEMAT in Madrid and have continued uninterrupted since 1975. In addition to medical examinations, measurements were made to detect Pu and, more recently Am^{241} in the body and in urine. To date 646 people, about 84% of the residents, have been measured at least once. Trace levels of plutonium have been detected in 52 residents that have been checked. Internal radiation doses have been estimated for these levels. The maximum committed effective dose equivalent (CEDE) derived from urine excretion of Pu^{239} was as follows:

Table 4. PALOMARES RESIDENTS MAXIMUM COMMITTED EFFECTIVE DOSE EQUIVALENT

NUMBER OF RESIDENTS	DOSE (rem) (*)
22	5.0 or less
22	5.0 to 10.0
8	10.0 to 20.0

(*) The doses were estimated by Spanish scientists in Madrid using models and methods provided by Oak Ridge National Laboratory (ORNL). They used the biokinetic plutonium excretion model of Laggett and Eckerman (1987) to estimate intake, and tried to account for both the initial intake and subsequent long-term chronic exposure to airborne plutonium from a very limited amount of bioassay data. The CEDE's were then derived directly from ICRP Publication 30 Supplement tables. This method used to interpret the bioassay data and estimate intakes is conservative, and the Spanish scientists have very likely over-estimated the actual intakes and subsequent internal doses.

By assuming a Gaussian distribution of the urinary excretion values the average excretion rate was found to be 350 femto curies (fCi)/day. By assuming chronic inhalation of Pu^{239} over the 18 year period and using the standard excretion function for Pu^{239}, one can derive an annual intake level of about 13 picocuries/year (pCi/yr). This is from residual environmental plutonium from worldwide weapons testing and plutonium deposited from the accident. This quantity is equivalent to about 1% of the annual limit for the Spanish public from natural background levels in the environment in other areas of Spain not contaminated by the Palomares accident. The average annual effective dose to the residents of Palomares corresponding to this intake is calculated to be 4.2 millirem/year (mrem/yr).

In discussions with C. Rick Jones, Mr. Alvarez indicated concern over the allegation that a child died of leukemia after soldiers gave the child candy to go around and pick-up bomb parts after the accident. We have researched our records and have found no verification of this incident occurring. However, approximately one hour following the accident over 100 members of the Guardia civil, Spanish police, established an exclusion area around the crash and bomb sites and restricted access of residents to these areas. Also, no Palomares residents were utilized

for clean-up of wreckage and bomb debris. However, some Palomares farmers were hired to assist the Americans in filling drums with low level activity soil and vegetation. Plutonium exposures received by the farmers during this work was very low and did not exceed recommended exposure limits. Therefore, it appears unlikely that a child would have been asked to pick up bomb parts. Also, there has been no known incidence of leukemia in any U.S. worker exposed to Pu^{239}.

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APPENDIX I

In a study conducted by G. Voelz and J. Lawrence concerning medical follow-up of Manhattan Project plutonium workers, 26 white male subjects who worked with plutonium during World War II at Los Alamos National Laboratory were studied. They received periodic medical examinations over a period of 42 years to identify potential health effects. Inhalation was considered to be the primary mode of plutonium exposure for these workers. Estimates of individual plutonium depositions, including lung burdens, as of 1987 or at the time of death range from 1.4 to 86 nanocuries (nCi) with a median value of 13.5 nCi. Four persons from the original group had died as of 1987. The causes of death were lung cancer, myocardial infraction, accidental injury, and respiratory failure due to pneumonia and congestive heart failure. Subsequent to 1987, three additional deaths occurred from atherosclerotic heart disease, lung cancer and osteogenic bone sarcoma. This appears to be the first case in which a bone sarcoma has been reported in a person exposed to plutonium. The estimated plutonium disposition in this man at the time of death is 15 nCi. However, while working at Los Alamos in August 1945 he received a wound to his thumb that became contaminated with a plutonium solution. The wound resulted in an uptake of approximately 2 nCi of plutonium. None of these workers have been diagnosed with leukemia. The plutonium exposures of these Manhattan Project workers expressed in terms of their CEDE, ranged from 10 to 850 rem.

Of approximately 400 beagle dogs, used in life-span studies and exposed to insoluble plutonium oxide or soluble plutonium nitrate at Pacific Northwest Laboratory (PNL) between 1960 and 1975, none have had leukemia. Intakes ranged from a few nanocuries to about 10,000 nanocuries of Pu^{239}. Lung tumors were observed, increasing with exposure, in dogs exposed to Pu^{239} oxide, and bone tumors were observed in dogs exposed to Pu^{239} nitrate. Both lung tumors and bone tumors were observed in dogs exposed to Pu^{238} oxide, a form that is more easily transported because it has a higher specific activity than Pu^{239}.

According to the International Commission on Radiological Protection (ICRP, 1986), a member of the public who receives 20 rem CEDE has 1 chance in 125 of contracting cancer. This is the highest projected CEDE among the monitored residents of Palomares. For a committed effective dose equivalent of 10 rem, the chances are 1 in 250; for 5 rem, 1 in 500; for 1 rem, 1 in 2500.

There is roughly a 70% chance that there will be zero (0) cancers resulting from the collective plutonium exposure in the 568 Palomares residents who were monitored, and roughly a 30% chance of one (1) cancer caused by plutonium exposure in this population. The chances of two or more cancers being caused by Pu exposure are slight. In an average population there is a 20-25% chance of developing cancer based on the normal incidence of cancer in the population.

Natural background radiation, excluding indoor radon, results in radiation doses of 0.1 rem per year from natural background radiation during a period of 15 years. Thus, the collective CEDE estimated from the bioassay data are comparable to the collective CEDE these same people received from natural background radiation. The most highly exposed persons are estimated to have received ten times more dose from Pu than from natural background during a 15-year period.

Collective CEDE (a simple summation of everyone's) from plutonium exposure among those 516 Palomares residents whose urine results were "below detectible" can be estimated by assuming a lognormal distribution. The collective CEDE is then estimated to be about 900 person-rem.

The potential radiation doses were calculated from exposure to the environmental levels of plutonium from data published in Iranzo, et al. (1987). The reported soil contamination at air sampling station 2-2 in Figure 1 of that article (which appears to be the location of the nearest house downwind) was 3.2 microcuries/square meter (uCi/m^2). This surface contamination was assumed to exist at the start of the exposure period with no reduction from cleanup, but with reduction for leaching to lower soil depths. All of the plutonium was assumed to be finely divided Pu^{239} on the soil surface. Re-suspended Pu was assumed to be class Y, but the Pu^{239} in foods was taken to be class W as recommended by the ICRP (1986). Doses calculated were 50-year CEDE values accumulated from 50 years of intake of the Pu. Doses were calculated using Version 1.485 of the GENII software package (Napier, et al. 1988). The calculated cumulative radiation dose was 5 rem; and the CEDE from the first year's exposure was 3 rem. This result is in the range of some of the doses calculated from the bioassay data.

For comparison, doses were calculated based on 50 years of exposure to the average air concentration reported by Irenzo, et al. 1987) for air station 2-2 located near the 3.2 uCi/m^2 isopleth. The reported 15-year average concentration was $5.2E^{-05}$ becquarels/cubic meter (Bq/m^3). This result is much lower than the doses based on either the soil contamination data or the bioassay data.

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